# 177-207 GHz Radiometer Front End: Single Sideband Measurements

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*ABSTRACT - Twenty years of progress in 200 GHz receivers for spaceborne remote sensing has yielded a 180-220 GHz technology with maturing characteristics, as evident by increasing availability of relevant hardware, paralleled by further refinement in receiver performance requirements at this spectrum band. The 177-207 GHz superheterodyne receiver, for the Earth observing system (EOS) microwave limb sounder (MLS), effectively illustrates such technology developments. This MLS receiver simultaneously detects six different signals, located at sidebands below and above its 191.95 GHz local-oscillator (LO).*

*The paper describes the MLS 177-207 GHz receiver front-end (RFE), and provides measured data for its lower and upper sidebands. Sideband ratio data is provided as a function of IF frequency, at different LO power drive, and for variation in the ambient temperature.*

INTRODUCTION

The 191.95±15 GHz receiver of the MLS employs a mixer simultaneously producing (Table 1) six IF outputs, three of which originate at the lower RF sideband (191.95-15 GHz) and the other three at the upper RF sideband (191.95+15 GHz).

| RF [GHz] | | LO [GHz] | IM [GHz] | | IF [GHz] |
|---|---|---|---|---|---|
| LOWER | 177.265 | | | | 14.685 |
| [RF.] | 181.599 | 191.95 | | | 10.351 |
| BAND | 183.314 | | | | 8.636 |
| | | | 182.920 | @ | 9.030 |
| | | 191.95 | 179.543 | RF. | 12.407 |
| | | | 177.763 | BAND | 14.187 |

Table 1: MLS 191.95 GHz Receiver Spectrum Characteristics

As the table illustrates, each one of the 191.95 GHz MLS sidebands contains RF inputs (RF) and image (IM) inputs, therefore, IM rejection with a filter is not a practical option. In effect, this MLS receiver relies on the availability of a double sideband (DSB) mixer with superior single sideband (SSB) sensitivity - i.e., mixers yielding extremely low noise temperature and a side-band ratio which approximates unity over a RF band spanning 30 GHz.

A mixer is the prime determinant of the RF sideband characteristics of a super-heterodyne receiver - especially at high millimeter-wave (MMW) frequencies, where a low noise MMW amplifier is not available to precede the mixer. The DSB inputs, i.e. upper/lower $RF_+/RF_-$ sideband, respectively, down-convert simultaneously to the same output IF band, following the relation $f_{IF} = |f_{LO} - f_{RF\pm}|$. Mixers employing nonlinear resistive devices exhibit theoretically identical RF-to-IF power conversion loss [1], for $f_{RF\pm}$ inputs symmetrically paired $2 \times f_{IF}$ apart relative to the frequency $f_{LO}$ of the local oscillator. Practically, DSB mixer operation is spectrum bounded: high-end bound, by the bandwidth of the mixer's circuit and the parasitic elements associated with a nonlinear resistive device, and low-end bound, by the frequency stability of the LO.

Progress at Aerojet in RF and IF circuit design of subharmonic (x2) mixers [2] and improvements at University of Virginia in mixer Schottky diode technology [3] are the prime facilitators of the MLS 191.95±15 GHz RF side bands characteristics reported in this paper.

## SINGLE SIDEBAND TESTS SETUP

Single sideband (SSB) measurements had been performed at JPL on this MLS RFE in the 177-207 GHz RF band and 8-15 GHz IF band. The setup is based on a parallel grid Fabry-Perot interferometer (FPI) configuration previously described [4], and required some modifications to facilitate an IF up to 15 GHz. The test setup was originally constructed for measuring mixer conversion loss at each sideband for IF frequencies up to about 12 GHz. A minimum grid spacing of about 2900 $\mu m$ accommodated such test capabilities, and determined the orders of resonance of the parallel grid. A higher IF frequency requires lower orders of resonance - with a minimum grid spacing of less than 1000 $\mu m$ - to insure avoidance of aliasing of the lower and upper sidebands between consecutive resonance orders of the grids. Reduction in grid spacing required installing a shim on the step micrometer shaft driving the linear slide assembly holding one of the two parallel grids. The linear variable differential transformer (LVDT) home reference was then readjusted so as to indicate home position to the controlling computer at a position close to the minimum grid spacing distance.

The setup facilitates relative measurements of RFE conversion loss at the lower sideband ($L_-$) and the upper sideband ($L_+$), for which the mixer is assumed the sole determinant. The specific spectrum of a SSB application determines the relations between $RF_-$ and $RF_+$, and RF and IM, respectively, to yield a sideband ratio $L_{RF}/L_{IM}$. This ratio enables the calculation of the receiver's SSB noise temperature ($T_R(SSB)$) from measured receiver DSB noise temperature ($T_R(DSB)$).

**The relation between SSB and DSB receiver noise-temperature**

$$T_R(SSB) = T_R(DSB) \times (1 + (L_{RF}/L_{IM}))$$

**$T_R(DSB)$ is measured by the Y-factor ("Hot" and "Cold" loads) method**

$$T_R(DSB) = (T(RF_{Hot}) - Y \times T(RF_{Cold}))/(Y-1)$$

SINGLE SIDEBAND MIXER MEASURED PERFORMANCE

The MLS 191.95 GHz RFE is designed to exhibit $T_R(DSB) \approx 1000$ K over an IF of 8-15 GHz, yielding $T_R(SSB) \leq 3000$ K (sidebands imbalance ($\leq 2$) is accommodated) over the 177-207 GHz RF band. Figure 1 summarizes MLS receiver DSB and SSB measurements at nominal operation conditions of base temperature 22.5°C, and an optimum 91.95 GHz LO power drive (+5 dBm). Figure 1 shows measured $T_R(SSB)$ data in comparison with measured $T_R(DSB)$ data. The measured DSB data is converted in the figure to a SSB receiver yielding perfect sideband balanced $\langle T_R(SSB) \rangle = 2 \times T_R(DSB)$. Hence, the difference between $T_R(SSB)$ and $\langle T_R(SSB) \rangle$ in the figure illustrates $L_{RF}/L_{IM}$ deviation from perfect balance.

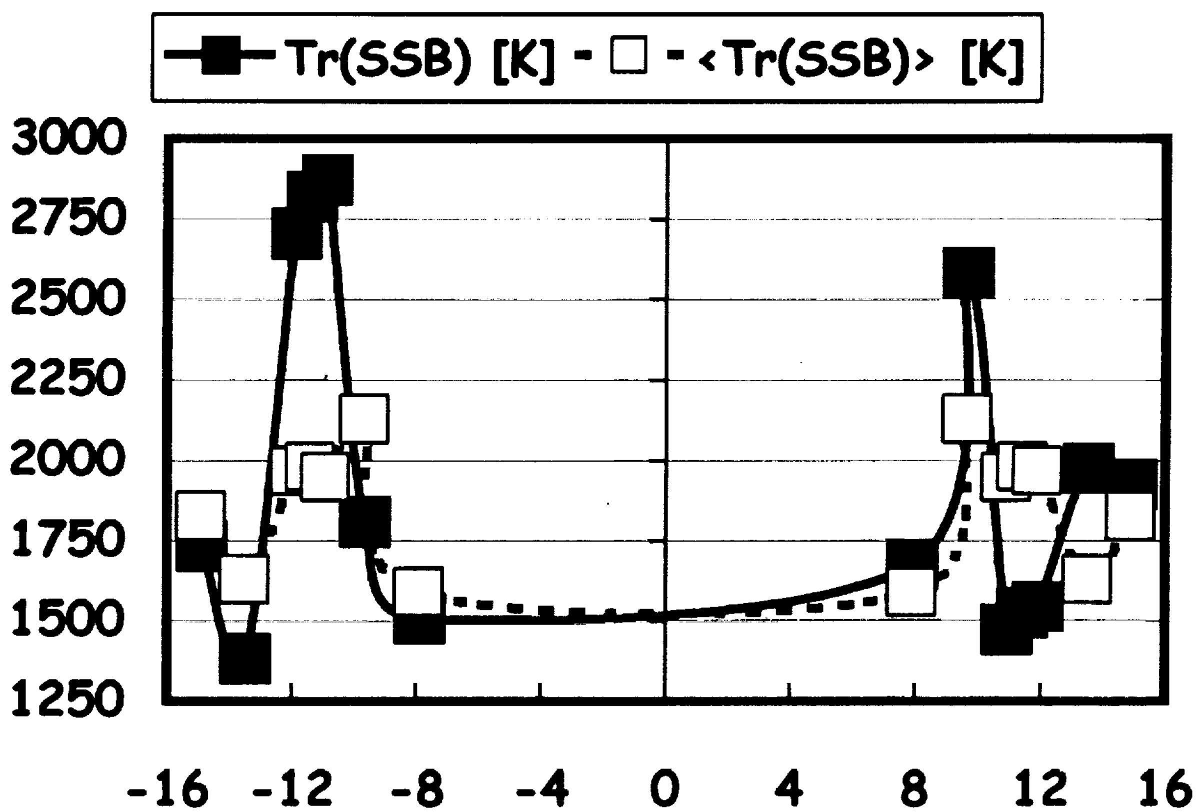
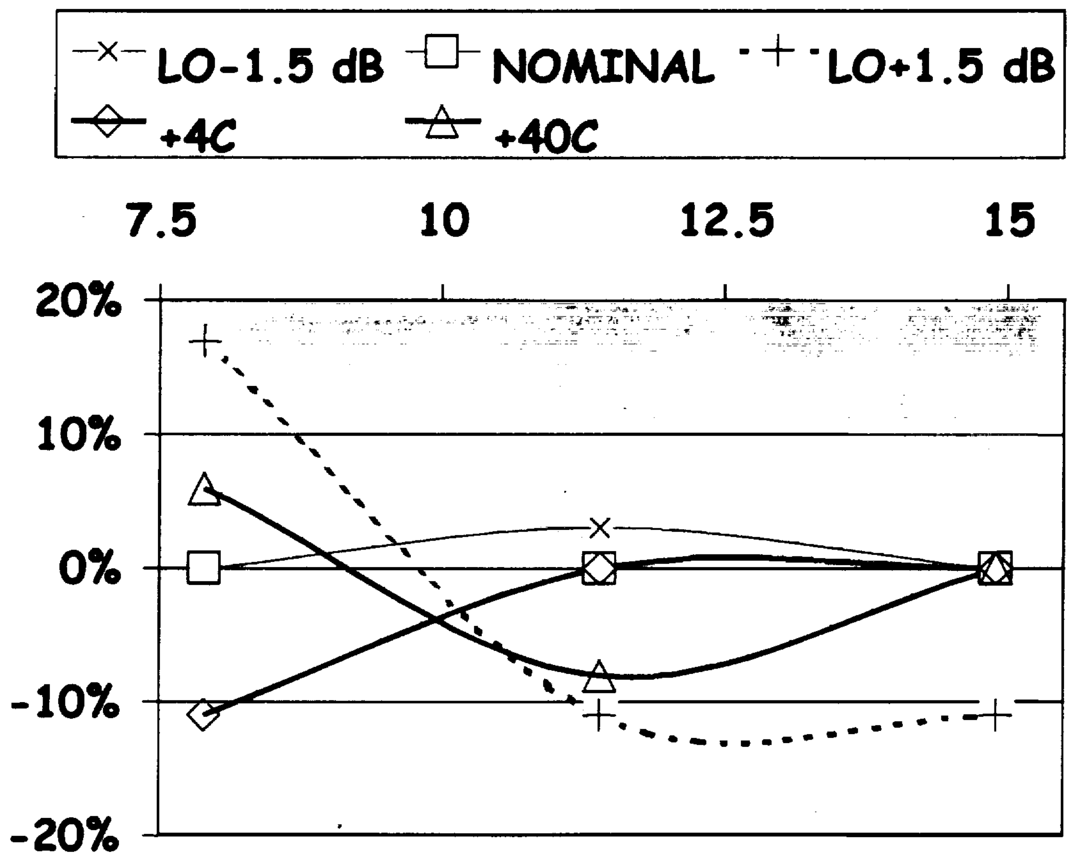


Figure 2 depicts the percent variation in sideband balance, relative to the nominal operation conditions, for changes in the receivers ambient temperature (22.5°C±17.5°C) and variation in LO power drive (+5dBm±1.5dBm).



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